

# PROTOCOL

January 2023

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## Weymouth Compressor Station Solar Taurus Turbine Emissions Testing

*Prepared for*

**Algonquin Gas Transmission, LLC**

Weymouth Compressor Station

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Waltham, MA 02451

*Prepared by*



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# PROTOCOL

## Weymouth Turbine Emissions Testing

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## **1 INTRODUCTION**

### **1.1 Overview**

Canomara LLC (CM) has been contracted by Algonquin Gas Transmission, LLC (AGT), a business unit of Enbridge, Inc. (Enbridge), to conduct compliance emissions testing on one Solar Taurus 60-7802 natural gas fired turbine located at the Weymouth Compressor Station at 54 Bridge Street in North Weymouth, MA. The purpose of the testing is to demonstrate compliance with the testing requirements of Massachusetts Department of Environmental Protection (MassDEP) Plan Approval Application Number SE-15-027 and 40 CFR 60 Subpart KKKK. Testing is currently scheduled for February 15 and 16, 2023.

### **1.2 Contact Information**

Evan Bali of CM will be the project manager for the test program. Ms. Kathryn Brown of AGT/Enbridge will coordinate sampling with plant operations at the compressor station. Benjamin Wankum of AGT/Enbridge is the station supervisor. John Paino is the MassDEP Southeast Region representative. Contact information is summarized below.

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## 2 SCOPE OF WORK

### 2.1 Test Matrix

CM will conduct emissions testing at the exhaust ductwork of the Solar Taurus 60 in accordance with US EPA test methods. The testing will occur while the turbine is operating within plus or minus 25 percent of the manufacturer's maximum design capacity at ISO conditions to satisfy the MassDEP plan approval and subpart KKKK. The ambient temperature shall be greater than 0°F. Table 2-1 contains the list of test parameters and applicable emissions limits.

**Table 2-1: Solar Turbine Test Matrix  
Weymouth Compressor Station**

Parameter	Methods <sup>1</sup>	Tests and Duration	MassDEP Limits <sup>2,3</sup>
Oxygen (O <sub>2</sub> ) Carbon Dioxide (CO <sub>2</sub> )	EPA 3a	3, 60-minute	N/A
Oxides of Nitrogen (NO <sub>x</sub> )	EPA 7e	3, 60-minute	9 ppmvd @ 15% O <sub>2</sub> 0.94 tpm 10.03 tpy
Carbon Monoxide (CO)	EPA 10	3, 60-minute	1.25 ppmvd @ 15% O <sub>2</sub> 2.18 tpm 17.28 tpy
Volatile Organic Compounds (VOC)	EPA 25a/18	3, 60-minute	2.4 ppmvd @ 15% O <sub>2</sub> 0.30 tpm 2.64 tpy
Particulate Matter (PM <sub>2.5</sub> ) <sup>1</sup>	EPA 1-5/202	3, 240-minute	0.0066 lb/MMbtu 0.18 tpm 1.99 tpy

1. PM<sub>2.5</sub> will be conducted in accordance with EPA Method 5 and 202 where total particulate matter will be reported as PM<sub>2.5</sub> by combining filterable and condensable particulate matter.
2. Federal limits (40 CFR 60 KKKK) for NO<sub>x</sub> are 25 ppmvd @15% O<sub>2</sub> or 1.2 lb/MWh.
3. Limits apply to the turbine at ambient temperatures greater than 0 degrees F.

**2.2 Test Schedule**

Table 2-2 contains the schedule for the emissions testing.

**Table 2-2: Test Schedule**

<b>Day</b>	<b>Activities</b>	<b>Crew Size</b>	<b>Time</b>
1	Equipment Setup	3	8 hrs
2	Two 240-minute tests	3	10 hrs
3	One 240-minute test	3	8 hrs
4	Contingency	3	8 hrs

### **3 PROCESS DESCRIPTION**

The Weymouth Compressor Station is located at 54 Bridge Street in North Weymouth, MA and is one of several compressor stations operated along AGT's interstate natural gas pipeline system.

The Solar Taurus 60-7802 is a natural gas fired simple cycle compressor turbine with a maximum rated capacity of 73.30 MMBtu/hr on a high heating value basis and a maximum fuel firing rate of 71,863 scf/hr at ambient temperatures above 0°F. Testing will occur while the turbine is operating within plus or minus 25% of the manufacturer's maximum design capacity at ISO conditions (67.14 MMBtu/hr) to satisfy the requirements of the Plan Approval and Subpart KKKK. Solar's proprietary "So-Lo-NOx" staged combustion system is utilized for the control of NO<sub>x</sub> emissions and the turbine is equipped with an oxidation catalyst for the control of CO and VOC.

Operating parameters will be recorded by the facility at minimum of 15-minute intervals during the turbine emissions testing. The following parameters will be recorded.

Compressor Data:

- Station gas flow rate (MMSCFD)
- Compressor suction and discharge pressures (PSIG)
- Compressor suction and discharge temperatures (°F)

Turbine Engine Data:

- Fuel flow rate (MSCFH)
- Heat Input (MMBtu/hr, calculated)
- Gas producer speed (NGP %)
- Power turbine speed (NPT %)
- Power turbine inlet and outlet air temperatures (°F)
- Power turbine discharge pressure (PCD PSIG)
- Oxidation catalyst inlet temperature (°F)
- Oxidation catalyst pressure drop (inches H<sub>2</sub>O)

#### 4 SAMPLING & ANALYTICAL PROCEDURES

Table 4-1 lists the reference methods which will be followed to conduct emissions testing. Table 4-2 contains information about the instrumental reference method analyzers and measurements ranges to be used during this test program. Appendix A contains detailed descriptions of the methods to be used during this test program.

**Table 4-1: Turbine Reference Methods**

Method	Description
EPA 1	Sample and Velocity Traverses for Stationary Sources
EPA 2	Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)
EPA 3a	Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 4	Determination of Moisture Content in Stack Gases
EPA 5	Determination of Particulate Matter from Stationary Sources
EPA 7e	Determination of Nitrogen Oxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 10	Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)
EPA 18	Gaseous Organic Compound Emissions by Gas Chromatography (Direct Interface Method)
EPA 25a	Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer
EPA 202	Method for Determining Condensable Particulate Emissions from Stationary Sources

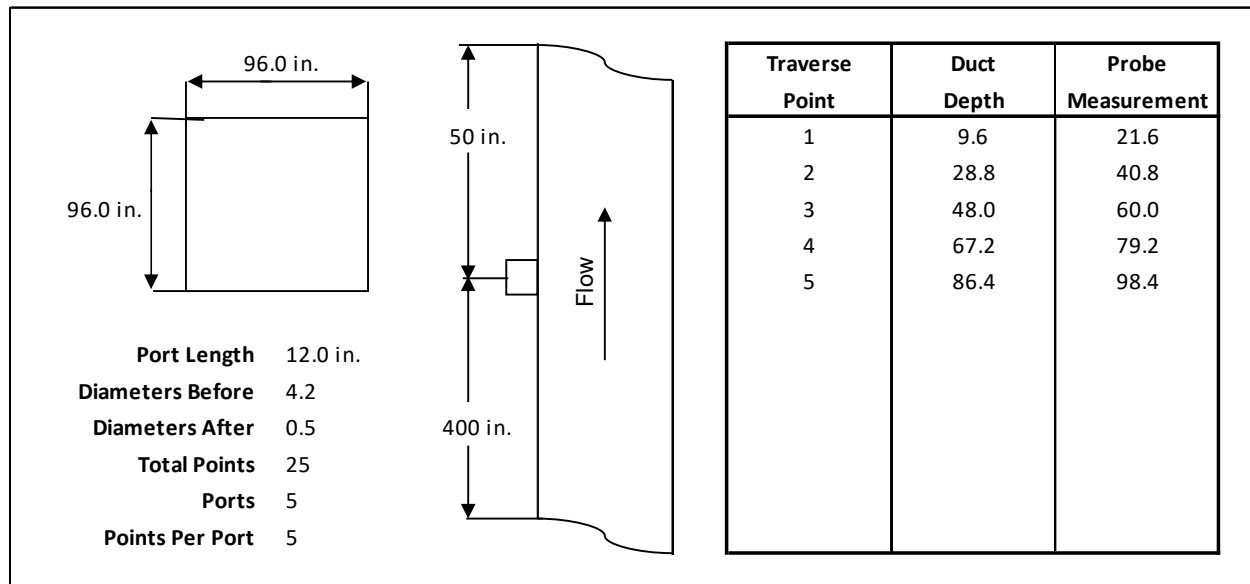
**Table 4-2: Turbine Instrumental Reference Method Analyzers**

Constituent	Analyzer	Detector	Span
O <sub>2</sub>	TAPI T200H	Paramagnetic	22 %
CO <sub>2</sub>	TAPI T300M	Non-Dispersive Infrared	18 %
NO <sub>x</sub>	TAPI 200H	Chemiluminescent	12 ppm
CO	TAPI T300M	Non-Dispersive Infrared	12 ppm
VOC	Vig 20 SRI 8610	Flame Ionization Gas Chromatography	10 ppm

#### 4.1 Sampling Locations

Turbine sampling will be conducted using five ports on the 96 x 96-inch horizontal exhaust duct prior to the vertical stack. A three-point stratification test will be conducted in accordance with EPA Method 7e and particulate traverse points for the turbine are presented in Figure 4-1.

**Figure 4-1: Turbine Traverse Points**





**5 QUALITY ASSURANCE**

CM's quality assurance program is designed so that work is performed by competent, experienced individuals using properly calibrated equipment, approved procedures for sample collection, recovery, and analysis and proper documentation. This ensures the integrity of data collected, processed, and reported on each project.

All final project deliverables are reviewed by an independent peer reviewer. Additional project specific quality assurance requirements are based on client contracts, local, state, or regional environmental regulations, and quality requirements and guidelines included in published sampling and analytical methods. Specific quality assurance procedures and acceptance criteria for this test program can be found in Appendix A.

# **APPENDIX A**

## **SAMPLING METHODS**

# EPA Method 1

## Sample and Velocity Traverses for Stationary Sources

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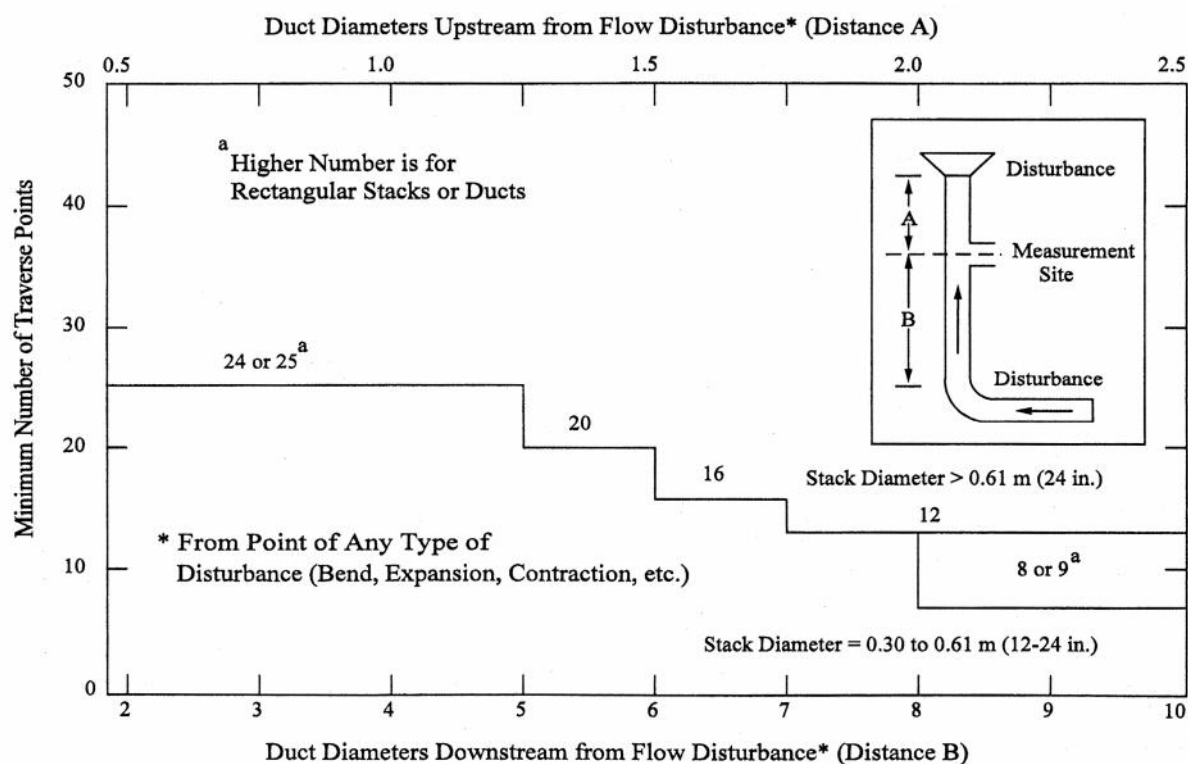
### SUMMARY

A measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. Traverse points are then located within each of these equal areas.

### SITE SELECTION

- Sampling or velocity measurements must be taken at a position at least 2 stack diameters downstream and a half diameter upstream from any flow disturbance.
- The minimum allowed number of traverse points can be used when there is at least 8 stack diameters downstream and 2 stack diameters upstream.
- For particulate traverses refer to table 1 to determine the required number of traverse points
- For velocity traverses refer to table 2 to determine the required number of traverse points
- For circular stacks, locate the traverse points on two perpendicular diameters according to the diameter percentages listed in table 3.
- For rectangular stacks, divide the stack into as many equal areas as traverse points and locate each traverse point in the center of each area.
- Verify the absence of cyclonic flow using a Type S pitot tube and the manometer nulling technique.

**Table 1**  
**Particulate Traverses**

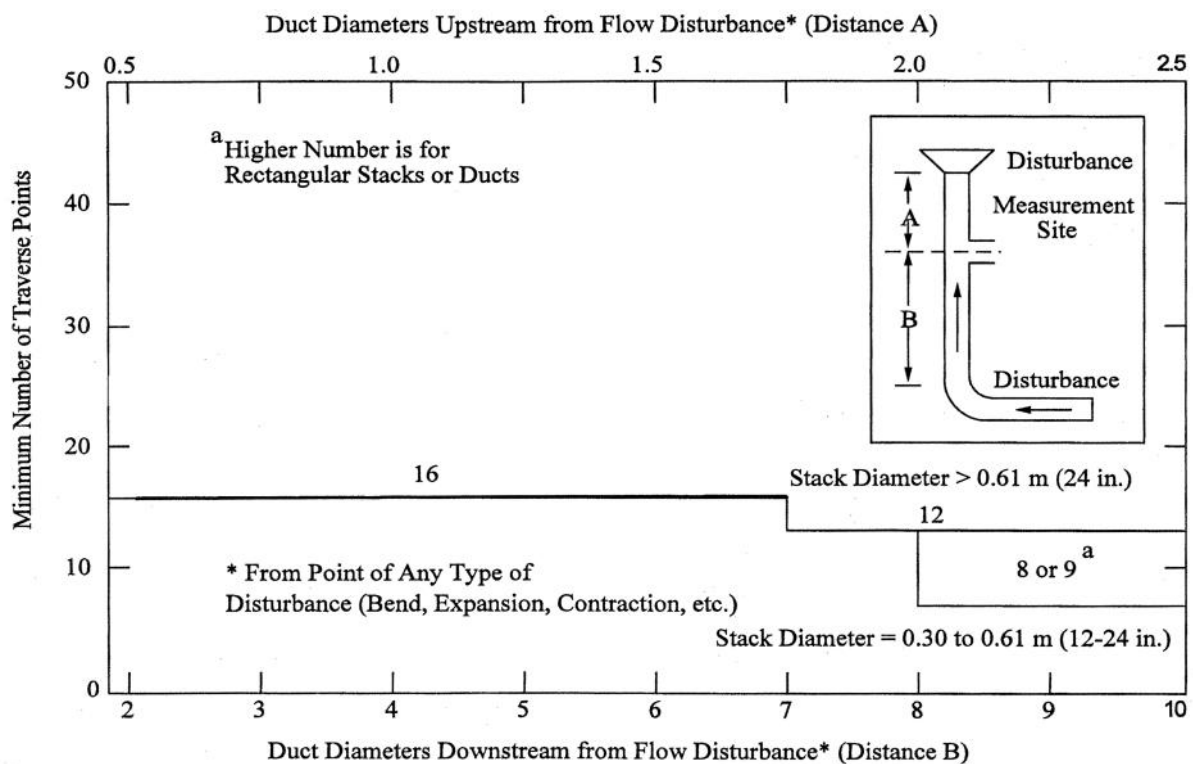


Revised: 08/2/2018

# EPA Method 1

## Sample and Velocity Traverses for Stationary Sources

**Table 2**  
**Velocity Traverses**



**Table 3**  
**Location of Traverse Points in Circular Stacks**

Traverse Point	Number of Traverse Points on a Diameter				
	4	6	8	10	12
1	6.7	4.4	3.2	2.6	2.1
2	25.0	14.6	10.5	8.2	6.7
3	75.0	29.6	19.4	14.6	11.8
4	93.3	70.4	32.3	22.6	17.7
5		85.4	67.7	34.2	25.0
6		95.6	80.6	65.8	35.6
7			89.5	77.4	64.4
8			96.8	85.4	75.0
9				91.8	82.3
10				97.4	88.2
11					93.3
12					97.9

## EPA Method 2

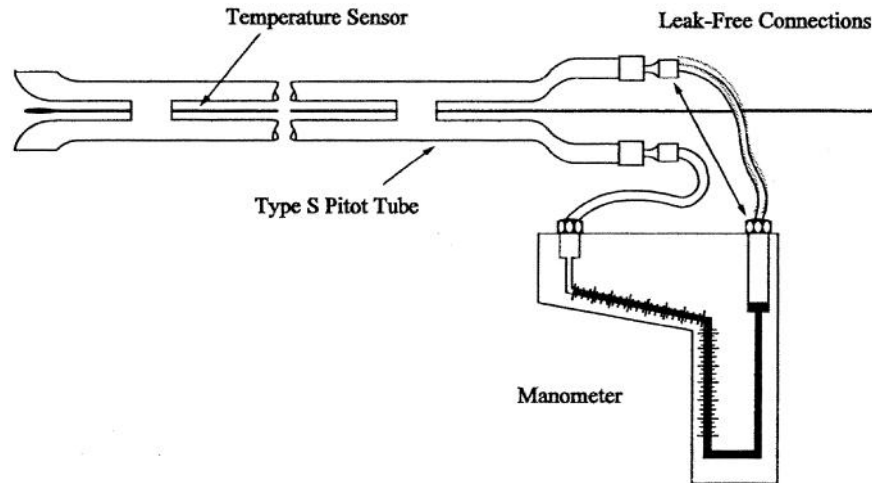
### Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

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#### SUMMARY

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Staustscheibe or reverse type) pitot tube.

#### MEASUREMENT EQUIPMENT



- Type S pitot tube constructed of stainless steel or other appropriate metal with a known coefficient.
- Leak free flexible tubing
- Differential pressure gauge such as in inclined manometer with a 10-inch water column with gradations of 0.01 - 0.1 inH<sub>2</sub>O for  $\Delta p$  readings greater than 0.05 inH<sub>2</sub>O.
- Temperature sensor such as a K-Type thermocouple attached to the pitot tube.

#### SAMPLING PROCEDURE

- It is recommended that a pre-test leak check be conducted by blowing into the positive side of the pitot tube until at least 3.0 inH<sub>2</sub>O is registered on the manometer. Block off the opening and observe that the reading remains stable for at least 15 seconds. Follow the same procedure on the negative side of the pitot tube using suction.
- Measure velocity head and temperature and the traverse points determined by EPA Method 1.
- Measure the static pressure in the stack.
- Determine the atmospheric pressure.
- Determine the stack gas dry molecular weight using EPA Method 3 or 3a.
- Determine moisture content using EPA Method 4, wet-bulb/dry-bulb, or saturation.

#### QUALITY ASSURANCE

- Pitot tube calibration by either geometric or wind tunnel measurements.
- Thermocouple calibration using an ice bath and boiling water.
- Pitot tube leak checks conducted before and after each velocity traverse.
- Maintain a properly leveled and zeroed manometer.

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## EPA Method 3a

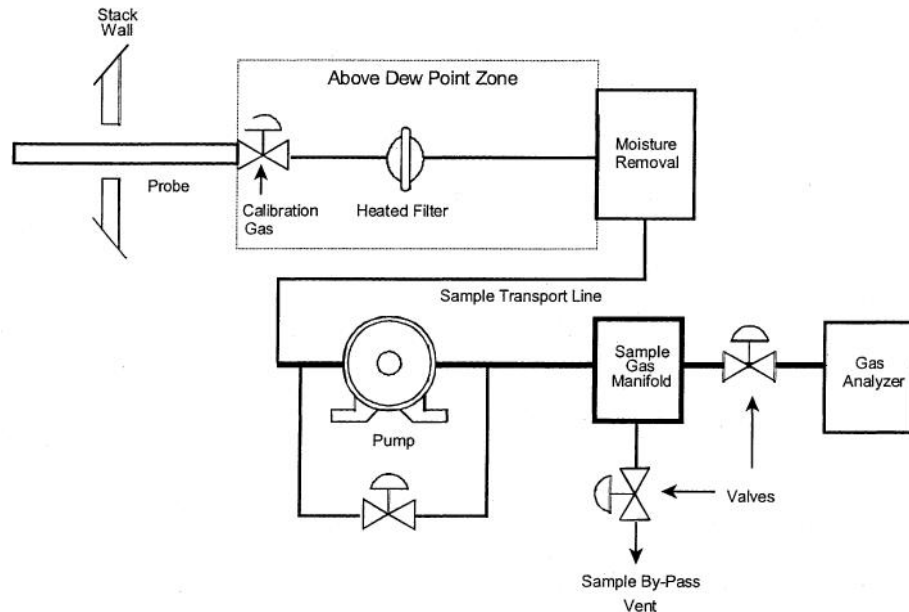
### Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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#### SUMMARY

Effluent gas is continuously conveyed to an analyzer for measuring the concentration of O<sub>2</sub> or CO<sub>2</sub>.

#### SAMPLING TRAIN



#### Components:

- Glass or stainless steel probe of sufficient length to traverse required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Sample line made of Teflon or other material that does not absorb or alter the sample gas.
- Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
- Analyzer capable of meeting all performance requirements that continuously measures O<sub>2</sub> or CO<sub>2</sub>.
- Computer based data acquisition system for recording measurements.

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## EPA Method 3a

### Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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#### SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test.
- Conduct an initial system bias check and response time test.
- Perform a stratification test to determine the number of sample traverse points unless the measurement is only being used to determine the stack gas molecular weight in which case a single measurement point may be used.
- Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
- Conduct a post-run system bias and drift assessment check.

#### QUALITY ASSURANCE

##### Measurement System:

- Calibration error is verified to be within  $\pm 2\%$  of the calibration span or  $\pm 0.5\%$  difference
- System bias is verified to be within  $\pm 5\%$  of the calibration span or  $\pm 0.5\%$  difference
- Drift is verified to be within  $\pm 3\%$  of the calibration span or  $\pm 0.5\%$  difference

##### O<sub>2</sub> or CO<sub>2</sub> Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is  $< 2.0\%$  full-scale range

##### Calibration Gas:

- Calibration uncertainty of  $\pm 2\%$  certified value
- Low-level gas  $< 20\%$  of calibration span
- Mid-level gas 40-60% of calibration span
- High-level gas sets the calibration span with test measurements 20-100% of this value

##### Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution  $\pm 0.5\%$  full-scale range
- Data recording frequency of 1-minute average
- Minute averages  $\pm$  calibration span
- Run average  $\pm$  calibration span

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## EPA Method 3a

### Determination of Oxygen and Carbon Dioxide Concentrations In Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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## CALCULATIONS

### Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

$C_V$  Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

$C_{DIR}$  Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

### System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

$C_S$  Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

### Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

$SB_{final}$  Post-run system bias, percent of calibration span

$SB_i$  Pre-run system bias, percent of calibration span

### Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

$C_{Gas}$  Average effluent gas concentration adjusted for bias, ppmv

$C_{Avg}$  Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

$C_O$  Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

$C_{MA}$  Actual concentration of the upscale calibration gas, ppmv

$C_M$  Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/2/2018





## EPA Method 4

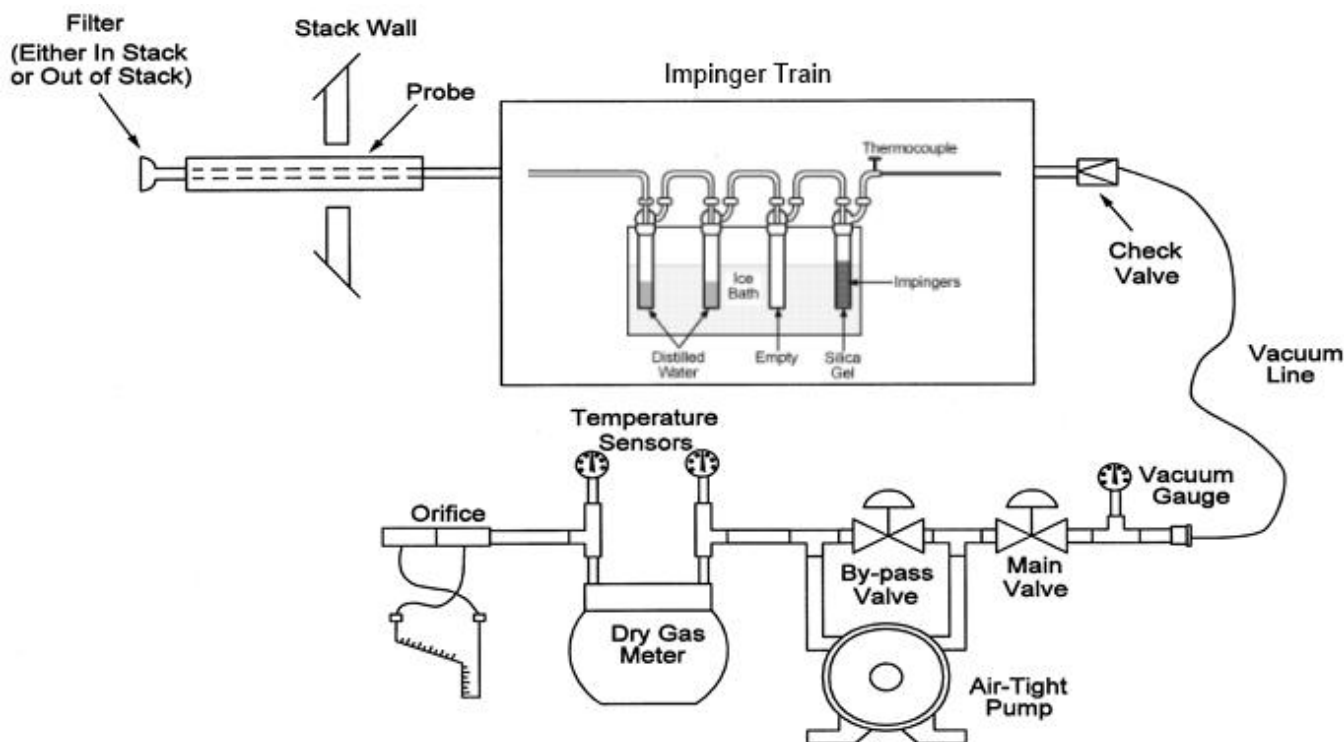
### Determination of Moisture Content in Stack Gases

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#### SUMMARY

A gas sample is extracted from the source at a constant rate. Moisture is removed from the sample stream by condensation and moisture is determined either gravimetrically or volumetrically.

#### SAMPLING TRAIN



#### Components:

- Stainless steel or glass probe sufficiently heated to prevent condensation.
- In-stack or heated out-of-stack filter
- Teflon sample line
- 4 impingers connected in series placed in an ice bath (impinger exit < 68 °F)
  1. Modified Greenburg-Smith, ~100 ml water
  2. Greenburg-Smith, ~100 ml water
  3. Modified Greenburg-Smith, empty
  4. Modified Greenburg-Smith, indicating silica gel
- Umbilical with leak-free vacuum line
- Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
- Inclined manometer or equivalent for measuring orifice values

Revised: 08/2/2018

## EPA Method 4

### Determination of Moisture Content in Stack Gases

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#### SAMPLING PROCEDURES

- Weigh the impinger train.
- Conduct a leak check from the tip of the probe at a vacuum of 15 inHg. Ensure that the leak rate is 0.020 cfm before starting a test run.
- Place the probe at the first sampling point.
- Begin sampling at a rate of approximately 0.75 cubic feet per minute. Collect sample data every 10 minutes including delta H, impinger outlet temperature, and dry gas meter inlet and outlet temperature.
- Conduct a post-test leak check from the tip of the probe or first impinger at a vacuum higher than the highest vacuum observed during sampling.

#### RECOVERY PROCEDURES

- Weigh the impinger train.
- Record the difference between the Post and Pre impinger train weights.
- Calculate the moisture content.

#### QUALITY ASSURANCE

##### Equipment:

- Dry gas meters are calibrated annually and after each field program.
- All glassware is cleaned prior to field use.
- Impinger exit temperature is monitored during testing to verify compliance with method specification.
- A leak check is conducted post run at a vacuum equal to or greater than the maximum value reached during the test run.
- The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.
- Temperature meters are calibrated annually and after each field use.

##### Data:

- Field data are recorded on prepared forms.
- Only reviewed spreadsheets are used to conduct data reduction calculations.
- All data and deliverables undergo peer review with a signoff form.

Revised: 08/2/2018



## EPA Method 4

### Determination of Moisture Content in Stack Gases

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#### CALCULATIONS

##### Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left( P_b + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

$V_{m(std)}$  Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf

$V_m$  Volume of gas sample as measured by dry gas meter, dcf

$Y$  Dry gas meter calibration factor

$T_{std}$  Standard absolute temperature, 528 °R

$P_{bar}$  Barometric pressure at the sampling site, inHg

$H$  Average pressure differential across the orifice meter, inH<sub>2</sub>O

$T_m$  Absolute average DGM temperature, °R

$P_{std}$  Standard absolute pressure, 29.92 inHg

##### Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

$V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf

$K_2$  0.04706 ft/ml for English units

$V_{lc}$  Total volume of liquid collected in impingers and silica gel

##### Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

$B_{ws}$  Water vapor in the gas stream, proportion by volume

$V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf

## EPA Method 5

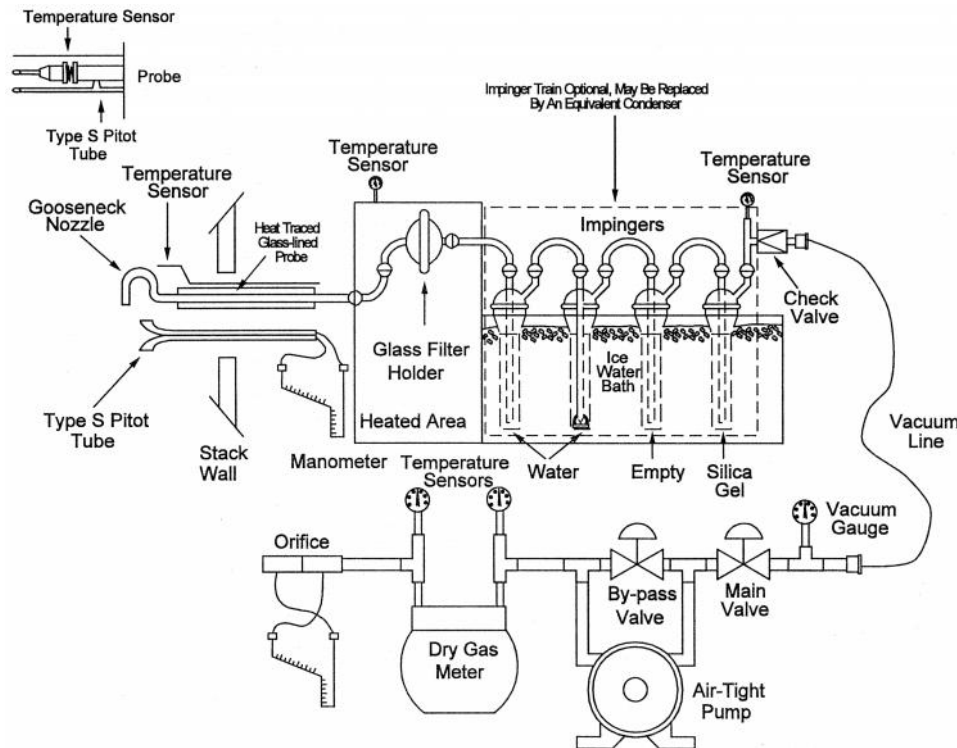
### Determination of Particulate Matter from Stationary Sources

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#### SUMMARY

Particulate matter (PM) is withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature of  $248 \pm 25$  °F. The PM mass, including any material that condenses at or above the filtration temperature, is determined gravimetrically after the removal of uncombined water.

#### SAMPLING TRAIN



#### Components:

- ) Stainless steel or glass button-hook nozzle with a sharp, tapered leading edge appropriately sized for isokinetic sampling
- ) Heated quartz or borosilicate glass lined probe ( $248 \pm 25$  °F) with attached Type S pitot tube and Type K thermocouple
- ) Heated 3-inch glass fiber filter in glass holder with Teflon frit ( $248 \pm 25$  °F)
- ) 4 impingers connect in series placed in an ice bath (impinger exit 68 °F)
  1. Modified Greenburg-Smith, ~100 ml water
  2. Greenburg-Smith, ~100 ml water
  3. Modified Greenburg-Smith, empty
  4. Modified Greenburg-Smith, indicating silica gel
- ) Umbilical with leak-free vacuum line
- ) Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
- ) Dual inclined manometer or equivalent for measuring velocity head and orifice values

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## EPA Method 5

### Determination of Particulate Matter from Stationary Sources

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#### SAMPLING PROCEDURES

- ) Select sampling site and minimum number of sampling points according to EPA Method 1. Mark an appropriately sized sampling probe with the points calculated for the location. Determine the sampling time per point 2 minutes.
- ) Determine appropriate nozzle size necessary to maintain isokinetic sampling conditions based on stack pressure, temperature, and velocity head range according EPA Method 2, stack molecular weight according to EPA Method 3/3a, and stack moisture content according to EPA Method 4.
- ) Calculate a k-factor based off the selected nozzle size and stack conditions. Assemble the sampling train as described above, weigh the impingers and place crushed ice around them.
- ) Conduct a leak check from the tip of the nozzle at a vacuum of 15 inHg. Ensure that the leak rate is 0.020 cfm before starting a test run.
- ) Place the probe at the first sampling point once all temperatures are within the required range.
- ) Begin sampling, making adjustments as necessary to maintain isokinetic sampling rate within  $\pm 10\%$ .
- ) Traverse the stack using the predetermined sampling points.
- ) Conduct a post-test leak check at a vacuum higher than the highest vacuum observed during sampling.
- ) Calculate % isokinetic for the run to validate the test.

#### RECOVERY PROCEDURES

- ) Weigh the impingers to determine moisture gain.
- ) Container 1 - Carefully remove the filter from its holder and place it in a labeled glass or polyethylene petri dish.
- ) Container 2 – Rinse and brush the nozzle, probe liner, and front half of the filter holder with reagent grade acetone (0.001 % residue) into a labeled glass or polyethylene sample container with a Teflon or other chemically resistant screw cap liner.
- ) Blank – Collect 200 ml of acetone from the wash bottle used to conduct recoveries into a labeled sample jar.

## EPA Method 5

### Determination of Particulate Matter from Stationary Sources

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#### QUALITY ASSURANCE

##### Equipment:

- ) Pitot tubes, thermocouples, nozzles, and dry gas meters are calibrated annually.
- ) All glassware is cleaned prior to field use.
- ) Probe, filter, and impinger exit temperatures are carefully monitored during testing to ensure the values are maintained within the appropriate range.
- ) The entire sampling train is leak checked post run from the tip of the nozzle at a vacuum equal to or greater than the maximum value reached during the test run.
- ) Sampling rate is verified to be within 10% isokinetic variation (90%-110%).
- ) The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.

##### Samples:

- ) New containers are used to collect samples.
- ) Each sample container is clearly labeled.
- ) A chain of custody is generated for all samples.
- ) Samples are transported upright in protective packaging.

##### Data:

- ) Field data are recorded on prepared forms.
- ) Only reviewed spreadsheets are used to conduct data reduction calculations.
- ) All data and deliverables undergo peer review with a signoff form.

## EPA Method 5

### Determination of Particulate Matter from Stationary Sources

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#### CALCULATIONS

##### Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left( P_b + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

$V_{m(std)}$  Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf

$V_m$  Volume of gas sample as measured by dry gas meter, dcf

$Y$  Dry gas meter calibration factor

$T_{std}$  Standard absolute temperature, 528 °R

$P_{bar}$  Barometric pressure at the sampling site, inHg

$H$  Average pressure differential across the orifice meter, inH<sub>2</sub>O

$T_m$  Absolute average DGM temperature, °R

$P_{std}$  Standard absolute pressure, 29.92 inHg

##### Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

$V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf

$K_2$  0.04706 ft<sup>3</sup>/ml for English units

$V_{lc}$  Total volume of liquid collected in impingers and silica gel

##### Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

$B_{ws}$  Water vapor in the gas stream, proportion by volume

$V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf

##### Particulate Concentration:

$$C_s = \frac{K_3 m_n}{V_{m(s)}}$$

$C_s$  Concentration of particulate matter in stack gas, dry basis, corrected to standard conditions, gr/dscf

$K_3$  0.0154 gr/mg for English units

$M_n$  Total amount of particulate matter collected, mg

Revised: 06/4/2020



**EPA Method 5****Determination of Particulate Matter from Stationary Sources**

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**CALCULATIONS (CONTINUED)**Isokinetic Variation:

$$I = \frac{100T_s \left[ K_4 V_{lc} + \frac{(V_m Y)}{T_m} \left( P_{bar} + \frac{\Delta H}{13.6} \right) \right]}{60 \theta v_s P_s A_n}$$

$T_s$	Absolute average stack gas temperature, °R
$K_4$	0.002669 ((inHg)(ft))/((ml)(°R)) for English units
$V_{lc}$	Total volume of liquid collected in impingers & silica gel, ml
	Total sampling time, min
$V_s$	Stack gas velocity, ft/sec
$P_s$	Absolute stack gas pressure, inHg
$A_n$	Cross-sectional area of nozzle, ft <sup>2</sup>

Alternative Post-Test Dry Gas Meter Calibration (EPA Method 5, Section 16.3)

$$Y_{qa} = \frac{q}{V_m} \left( \frac{0.0319 (T_m + 460) \times 29}{DH_{@} [P_b + (DH_{avg}/13.6)] M_d} \right)^{0.5} (DH^{0.5})_{avg}$$

 $Y_{qa}$  = Dry gas meter calibration check value, dimensionless $q$  = Total run time, min $V_m$  = Total sample volume measured by dry gas meter, dcf $T_m$  = Average dry gas meter temperature, °F $P_b$  = Barometric pressure, in. Hg0.0319 = (29.92/528)(0.75)<sup>2</sup> (in. Hg/°R) cfm<sup>2</sup> $DH_{avg}$  = Average orifice meter differential, in H<sub>2</sub>O $DH_{@}$  = Orifice meter calibration coefficient, in H<sub>2</sub>O $M_d$  = Dry molecular weight of stack gas, lb/lb-mole

29 = Dry molecular weight of air, lb/lb-mole

13.6 = Specific gravity of mercury

$$\text{Difference} = \frac{(Y_{qa} - Y)}{Y} \text{ within } \pm 5\%$$

Revised: 06/4/2020





## EPA Method 7e

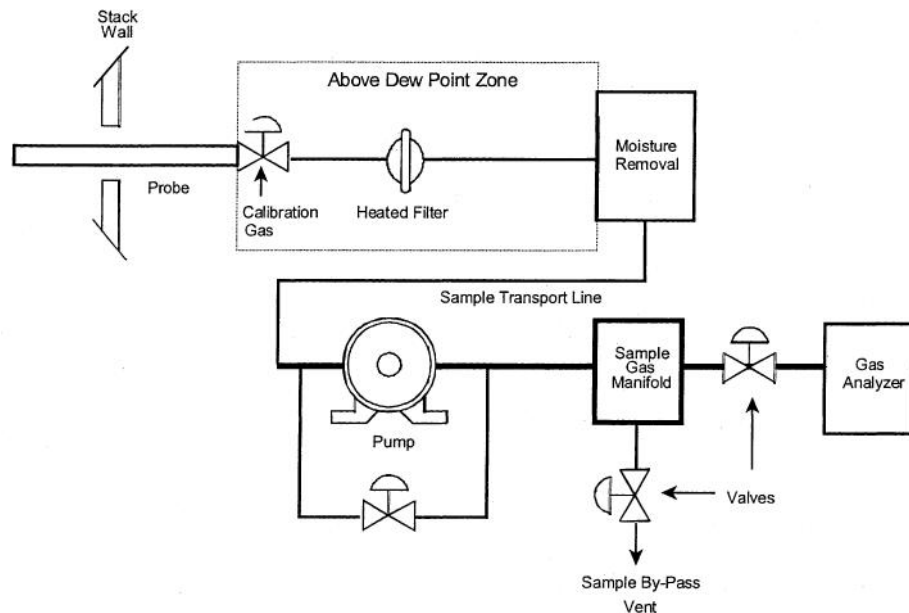
### Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Page 1 / 3

#### SUMMARY

A sample of the effluent gas is continuously conveyed to the analyzer for measuring the concentration of  $\text{NO}_x$  as  $\text{NO}_2$ .  $\text{NO}$  and  $\text{NO}_2$  may be measured separately or simultaneously, but for the purposes of this method  $\text{NO}_x$  is the sum of  $\text{NO}$  and  $\text{NO}_2$ .

#### SAMPLING TRAIN



#### Components:

- Glass or stainless steel probe of sufficient length to traverse required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Heated sample line (250°F) made of Teflon or other material that does not absorb or alter the sample gas.
- Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
- An analyzer capable of meeting all performance requirements that continuously measures  $\text{NO}_x$ .
- Computer based data acquisition system for recording measurements.

Revised: 08/2/2018

## EPA Method 7e

### Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Page 2 / 3

#### SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test.
- Conduct an initial system bias check and response time test.
- Conduct an NO<sub>2</sub> to NO conversion efficiency test if the analyzer being used performs this conversion to measure NO<sub>x</sub>.
- Perform a stratification test to determine the number of sample traverse points.
- Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
- Conduct a post-run system bias and drift assessment check.

#### QUALITY ASSURANCE

##### Measurement System:

- Calibration error is verified to be within  $\pm 2\%$  of the calibration span or  $\pm 0.5$  ppmv difference
- System bias is verified to be within  $\pm 5\%$  of the calibration span or  $\pm 0.5$  ppmv difference
- Drift is verified to be within  $\pm 3\%$  of the calibration span or  $\pm 0.5$  ppmv difference

##### NO<sub>x</sub> Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is  $< 2.0\%$  full-scale range
- Converter efficiency is verified to be  $\geq 90\%$  or demonstrate a decrease from NO<sub>xPeak</sub> of  $\geq 2\%$

##### Calibration Gas:

- Calibration uncertainty of  $\geq 2\%$  certified value
- Low-level gas  $< 20\%$  of calibration span
- Mid-level gas 40-60% of calibration span
- High-level gas sets the calibration span with test measurements 20-100% of this value
- Converter efficiency gas concentration is 40-60 ppm NO<sub>2</sub>

##### Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution  $\geq 0.5\%$  full-scale range
- Data recording frequency of  $\geq 1$ -minute average
- Minute averages  $\geq$  calibration span
- Run average  $\geq$  calibration span

Revised: 08/2/2018



## EPA Method 7e

### Determination of Nitrogen Oxides Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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## CALCULATIONS

#### Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

$C_V$  Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

$C_{DIR}$  Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

#### System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

$C_S$  Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

#### Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

$SB_{final}$  Post-run system bias, percent of calibration span

$SB_i$  Pre-run system bias, percent of calibration span

#### Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

$C_{Gas}$  Average effluent gas concentration adjusted for bias, ppmv

$C_{Avg}$  Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

$C_O$  Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

$C_{MA}$  Actual concentration of the upscale calibration gas, ppmv

$C_M$  Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/2/2018



## EPA Method 10

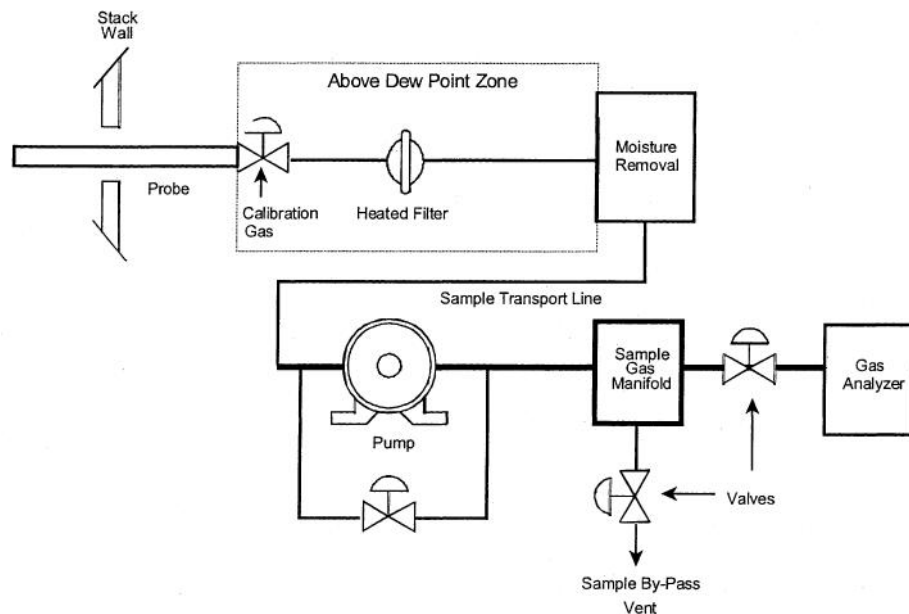
### Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

Page 1 / 3

#### SUMMARY

Effluent gas is continuously conveyed to an analyzer for measuring the concentration of CO. Alternatively, sample gas may be collected in a Tedlar bag followed by analysis with a calibrated analyzer.

#### SAMPLING TRAIN



#### Components:

- Glass or stainless steel probe of sufficient length to traverse required sample points.
- An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- Heated Sample line (250°F) made of Teflon or other material that does not absorb or alter the sample gas.
- Condenser or dryer to remove moisture from the sample gas if measuring on a dry basis.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases either directly to the analyzer or into the measurement system at the probe and to direct a portion of the sample to the analyzer while diverting the rest of the sample to a by-pass discharge vent.
- An analyzer capable of meeting all performance requirements that continuously measures CO.
- Computer based data acquisition system for recording measurements.

Revised: 08/2/2018

## EPA Method 10

### Determination of Carbon Monoxide Emissions from Stationary Sources (Instrumental Analyzer Procedure)

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#### SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test.
- Conduct an initial system bias check and response time test.
- Perform a stratification test to determine the number of sample traverse points.
- Position the probe at the first sampling point and purge the system for at least two times the response time. Traverse all required points sampling for equal time at each.
- Conduct a post-run system bias and drift assessment check.

#### QUALITY ASSURANCE

##### Measurement System:

- Calibration error is verified to be within  $\pm 2\%$  of the calibration span or  $\pm 0.5$  ppmv difference
- System bias is verified to be within  $\pm 5\%$  of the calibration span or  $\pm 0.5$  ppmv difference
- Drift is verified to be within  $\pm 3\%$  of the calibration span or  $\pm 0.5$  ppmv difference

##### CO Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is  $< 2.0\%$  full-scale range

##### Calibration Gas:

- Calibration uncertainty of  $\pm 2\%$  certified value
- Low-level gas  $< 20\%$  of calibration span
- Mid-level gas 40-60% of calibration span
- High-level gas sets the calibration span with test measurements 20-100% of this value

##### Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution  $\pm 0.5\%$  full-scale range
- Data recording frequency of 1-minute average
- Minute averages  $\pm$  calibration span
- Run average  $\pm$  calibration span

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Revised: 08/2/2018

## EPA Method 10

Determination of Carbon Monoxide Emissions from Stationary Sources  
(Instrumental Analyzer Procedure)

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### CALCULATIONS

#### Analyzer Calibration Error:

$$ACE = \frac{C_{DIR} - C_V}{C} \times 100$$

ACE Analyzer calibration error, percent of calibration span

$C_V$  Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

$C_{DIR}$  Measured concentration of a calibration gas when introduced in direct calibration mode, ppmv

CS Calibration span, ppmv

#### System Bias:

$$SB = \frac{C_S - C_{DIR}}{C} \times 100$$

SB System bias, percent of calibration span

$C_S$  Measured concentration of a calibration gas when introduced in system calibration mode, ppmv

CS Calibration span, ppmv

#### Drift Assessment:

$$D = SB_{final} - SB_i$$

D Drift assessment, percent of calibration span

$SB_{final}$  Post-run system bias, percent of calibration span

$SB_i$  Pre-run system bias, percent of calibration span

#### Effluent Gas Concentration:

$$C_{Gas} = (C_{Avg} - C_O) \times \frac{C_{MA}}{C_M - C_O}$$

$C_{Gas}$  Average effluent gas concentration adjusted for bias, ppmv

$C_{Avg}$  Average unadjusted gas concentration indicated by data recorder for the test run, ppmv

$C_O$  Average of initial and final system bias responses from the low-level (or zero) calibration gas, ppmv

$C_{MA}$  Actual concentration of the upscale calibration gas, ppmv

$C_M$  Average of initial and final system bias responses for the upscale calibration gas, ppmv.

Revised: 08/2/2018



## EPA Method 18

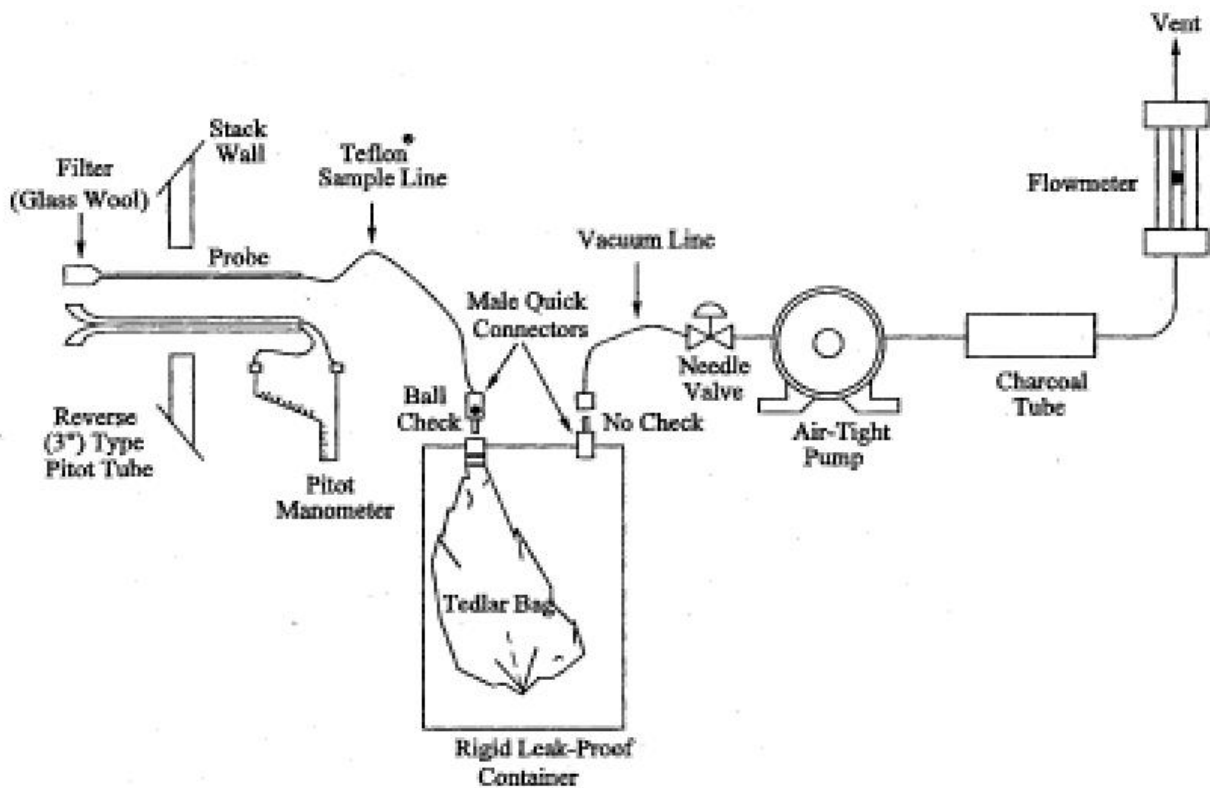
### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

Page 1 / 6

#### SUMMARY

Sample gas is collected in a Tedlar bag at a constant rate and the bag sample is analyzed by gas chromatography for volatile organic compounds. A sampling train schematic is shown below and photographs are attached.

#### SAMPLING TRAIN



#### Sampling Components:

- ✓ Glass or stainless steel probe of sufficient length to reach required sample points.
- ✓ An in-stack or out-of-stack filter made of material which is non-reactive to the sample gas. The filter is not required where no significant particulate matter is present.
- ✓ Sample line made of Teflon or other material that does not absorb or alter the sample gas.
- ✓ Rigid gas tight container with compression type fittings
- ✓ Flexible bags constructed of Tedlar or other inert material
- ✓ Gas flow meter or critical orifice flow controller
- ✓ Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.

#### Analytical Components

- ✓ SRI Inc. Model 8610C gas chromatograph, laptop computer with Peaksimple software and USB cable
- ✓ Restek MXT-1 60 meter steel capillary column (test protocol will specify other column type if required)

Revised: 01/4/2023

## EPA Method 18

### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

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- ) High purity hydrogen, nitrogen and air
- ) CGA 350, 580 and 590 gas cylinder regulators with 1/8-inch tubing connectors
- ) 1,000 cc gas syringe
- ) Printer (optional as all chromatography files are saved)

### SAMPLING PROCEDURES

- ) Assemble the sampling system and conduct a leak check.
- ) For critical orifice flow controllers, calibrate the sampling rate with a gas flow calibrator.
- ) Set sampling rate to fill a Tedlar bag approximately 80% full over the test period. A typical sampling rate is 0.16 liters per minute to collect a 9.6 liter sample in a 12 liter bag over a 1-hour period.
- ) Position the probe at the first sampling point and purge the system for at least two times the response time.
- ) Record sampling data on a prepared form. Sampling data may include dry gas meter volume, flow meter ball level, temperature, vacuum and pressure.

### ANALYTICAL PROCEDURES

- ) Set up SRI Model 8610C chromatograph in accordance with manufacturer specifications.
- ) Confirm that all calibration gas certifications are complete and not expired.
- ) Conduct a 3-level calibration on the gas chromatograph for each target compound using commercially available gas standards. Each gas standard must be analyzed three times and the responses must be within 5% of the mean for each target compound.
- ) Analyze samples after completing the initial calibration. Samples are also analyzed in triplicate and responses must be within 5% of the mean.
- ) Periodically analyze zero grade nitrogen or air to demonstrate system is contamination free.
- ) Prepare a bag recovery spike using one of the sample bags. The recovery spike is prepared using a gas syringe (see attached photograph) and one of the calibration standards. Inject a volume of standard gas into the sample bag to increase the target compound concentration by 40-60%. Analyze the spiked sample in triplicate and calculate recovery using the Method 18 controlled spreadsheet. Sample values are corrected using a spike recovery factor.
- ) After completing sample analyses, re-analyze the mid-level calibration gas in triplicate. If the average value of each target compound is within 5% of the initial value, the initial calibration can be used to quantify the samples. If the post-test calibration varies by more than 5% of the initial calibration, then the 3-point calibration must be repeated and both pre and post-test calibrations must be used for sample quantification.



## EPA Method 18

### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

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## QUALITY ASSURANCE

### Sampling System:

- ) Sample flow rate should be  $\pm 2\%$ .
- ) Leak rate should be 0.00 liters per minute at 5 inches Hg vacuum

### Chromatography Analysis:

- ) Standards, samples and spikes must be analyzed in triplicate and responses must be within 5% of the mean.
- ) Spike recovery must be within 70 – 130%.

### Calibration Gas:

- ) Calibration uncertainty of 2% certified value
- ) Gas used only prior to expiration date

## CALCULATIONS

### Triplicate Injection:

$$\text{Dev} = \frac{(\text{RP}_{\text{avg}} - \text{RP})}{R} \times 100$$

RP Chromatograph response in area units

$\text{RP}_{\text{avg}}$  Average response of three injections

Dev Deviation from the mean value

### Drift Assessment:

$$D = \text{SB}_{\text{final}} - \text{SB}_i$$

D Drift assessment, percent of calibration span

$\text{SB}_{\text{final}}$  Post-run system response for the mid-level gas

$\text{SB}_i$  Pre-run system response for the mid-level gas

### Spike Recovery Correction:

$$C_{\text{Gas}} = C_{\text{Avg}} \times R$$

$C_{\text{Gas}}$  Average effluent gas concentration adjusted for spike recovery, ppmv

$C_{\text{Avg}}$  Average unadjusted gas concentration for the test run, ppmv

R Recovery Factor

Revised: 01/4/2023



## EPA Method 18

### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

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#### Recovery Study:

#### EPA Method 18 Section 8.4.2 Recovery Study for Bag Sampling Example Calculation

	Sample ID	Post Analysis Sample Volume (l)	Un-Spiked Sample Response (u) (ppm)	Compound Volume in Sample (ul)	Standard Volume Added to Sample (L)	Standard Conc (ppm)	Compound Volume from Standard (ul)	Spiked Bag Total Conc (ppm)	Theoretical Spike Conc (s) (ppm)	Spiked Sample Response (t) (ppm)	(t-u)/s Recovery (%)
Compound 1	Run 1	6.977	0.0	0.0	0.400	9.4	3.752	0.51	0.51	0.50	98.3%

#### Spiked Sample Analysis

Injection No.	Concentration (ppm)				Deviation		
	1	2	3	average (t)			
Compound 1	0.50	0.50	0.50	0.50	0.0%	0.0%	0.0%

Recovery = (t-u)/s x 100

$$= (0.50-0.00)/0.51 \times 100 = 98.3\%$$

#### Bag Sample Volume meter Y= 0.9828

Temp (°F)	Meter Volume (liters)	Pbar	Standard Volume (liters)
60.0	7.055	30.08	7.127

#### Sample Volume Used for Initial Analyses

# of injections	rate (cc/min)	time (min)	Volume (liters)
3	50	1	0.15

#### Detection Limit

Detection limit is determined by analyzing the low standard seven times and applying a standard statistical analysis. An example of the detection limit determination is shown below.

Standard Conc (ppm)	Response (ppm) <sup>1</sup>							Average	Standard Deviation	MDL (ppm) <sup>2</sup>
	1	2	3	4	5	6	7			
1.00	1.181	1.129	1.166	1.171	1.183	1.185	1.182	1.1710	0.020	0.062

1. The low standard is analyzed 7 consecutive times.

2. MDL (ppm) = STDEV x 3.143

STDEV = standard deviation of the response for 7 injections of the low standard

3.143 = Student T-value for n-1 degrees of freedom at a 99% confidence

Revised: 01/4/2023



## EPA Method 18

### Gaseous Organic Compound Emissions by Gas Chromatography (Integrated Bag Sampling and Analysis)

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#### Mass Emission Rate

Pollutant mass emission rate in pounds per hour (lb/hour) is calculated from the measured concentration and exhaust gas flow rate as follows:

$$ER = \text{ppmw} \times \text{molecular weight} \times \text{scfm} \times 15.58 \times 10^{-8}$$

ER = emission rate (lb/hour)

ppmw = parts per million by volume – wet basis

scfm = standard cubic feet per minute (wet)

#### Mass Basis Destruction Efficiency

Mass basis destruction efficiency is calculated with measured pollutant flow rates at the control device inlet and outlet using the following calculation:

$$\text{Destruction Efficiency (\%)} = (ER_{\text{in}} - ER_{\text{out}}) / ER_{\text{in}} \times 100$$

ER<sub>in</sub> = control device inlet pollutant flow rate (lb/hour)

ER<sub>out</sub> = control device outlet pollutant flow rate (lb/hour)

## EPA Method 18

Gaseous Organic Compound Emissions by Gas Chromatography  
(Integrated Bag Sampling and Analysis)

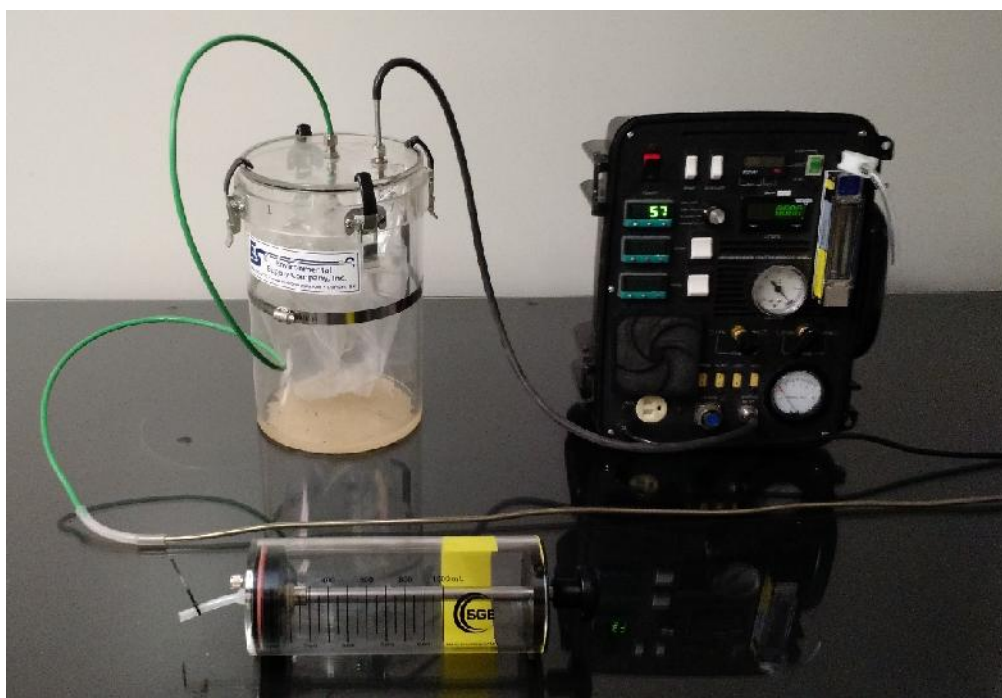
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### COMPONENT IMAGES

SRI, Inc. Model 8610C Gas Chromatograph:



EPA Method 18 Bag Sampling Device and Gas Syringe for Recovery Study:



Revised: 01/4/2023

## EPA Method 25a

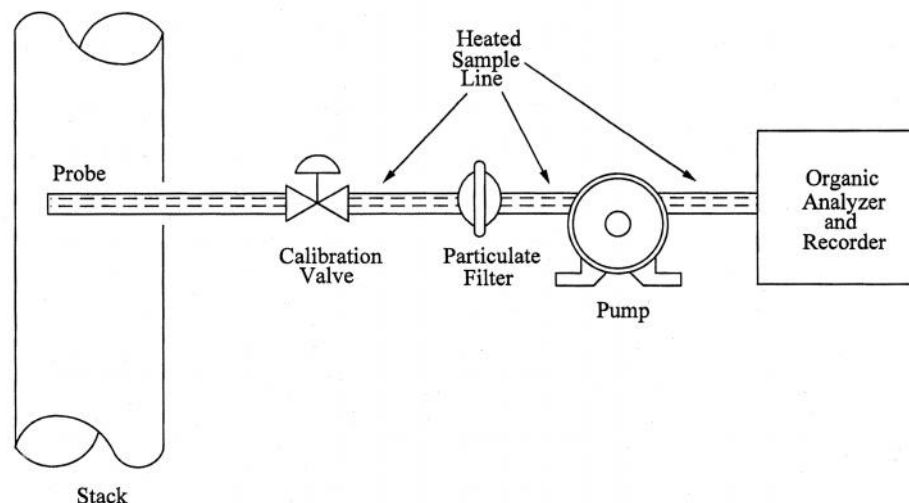
### Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

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#### SUMMARY

A gas sample is extracted from the source through a heated sample line and glass fiber filter to a flame ionization analyzer.

#### SAMPLING TRAIN



#### Components:

- Stainless steel probe heated to 220 °F.
- A glass fiber in-stack filter or a glass fiber out-of-stack filter heated to 220 °F. The filter is not required where no significant particulate matter is present.
- Teflon or stainless steel sample line heated to 220 °F.
- Leak-free pump constructed of non-reactive material to pull sample through the system at a sufficient rate to minimize the response time.
- Manifold constructed of non-reactive material to allow the introduction of calibration gases into the measurement system at the probe.
- Flame ionization analyzer capable of meeting all performance requirements.
- Computer based data acquisition system for recording measurements.

## EPA Method 25a

### Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

Page 2 / 3

#### SAMPLING PROCEDURES

- Assemble the sampling system and conduct a leak check.
- Confirm that all calibration gas certifications are complete and not expired.
- Conduct an analyzer calibration error test sending gas through the entire measurement system.
- Conduct a response time test.
- Position the probe so that sample is collected from the centrally located 10% area of the stack.
- Begin sampling after 2 times the sampling response time has passed.
- Conduct a post-run drift assessment check.

#### QUALITY ASSURANCE

##### Measurement System:

- Calibration error is verified to be within  $\pm 5\%$  of the calibration gas value
- Drift is verified to be within  $\pm 3\%$  of the span value

##### Analyzer:

- Analyzer used for testing has undergone manufacturer interference checks
- Analyzer resolution is  $< 2.0\%$  full-scale range

##### Calibration and Support Gas:

- Calibration uncertainty of 2% certified value
- High purity air zero gas  $< 0.1$  ppmv organic material
- Low-level calibration gas 25-35% of the applicable span value
- Mid-level gas 45-55% of the applicable span value
- High-level gas 80-90% of the applicable span value
- Fuel consisting of 100%  $H_2$

##### Data:

- Data collection and calculations are conducted on a reviewed computer based system
- Data resolution 0.5% full-scale range
- Data recording frequency of 1-minute average
- Minute averages calibration span
- Run average calibration span

Revised: 08/2/2018



## EPA Method 25a

### Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

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#### CALCULATIONS

##### Analyzer Calibration Error:

$$ACE = \frac{C_S - C_V}{C_V} \times 100$$

ACE Analyzer calibration error, percent of calibration gas value

$C_S$  Measured concentration of a calibration gas through the sampling system, ppmv

$C_V$  Manufacturer certified concentration of a calibration gas (low, mid, high), ppmv

##### Drift Assessment:

$$D = \frac{C_S - C_i}{C} \times 100$$

D Drift assessment, percent of span

$C_S$  Measured concentration of a calibration gas through the sampling system, ppmv

$C_i$  Initial analyzer response, ppmv

CS Calibration span, ppmv

## EPA Method 202

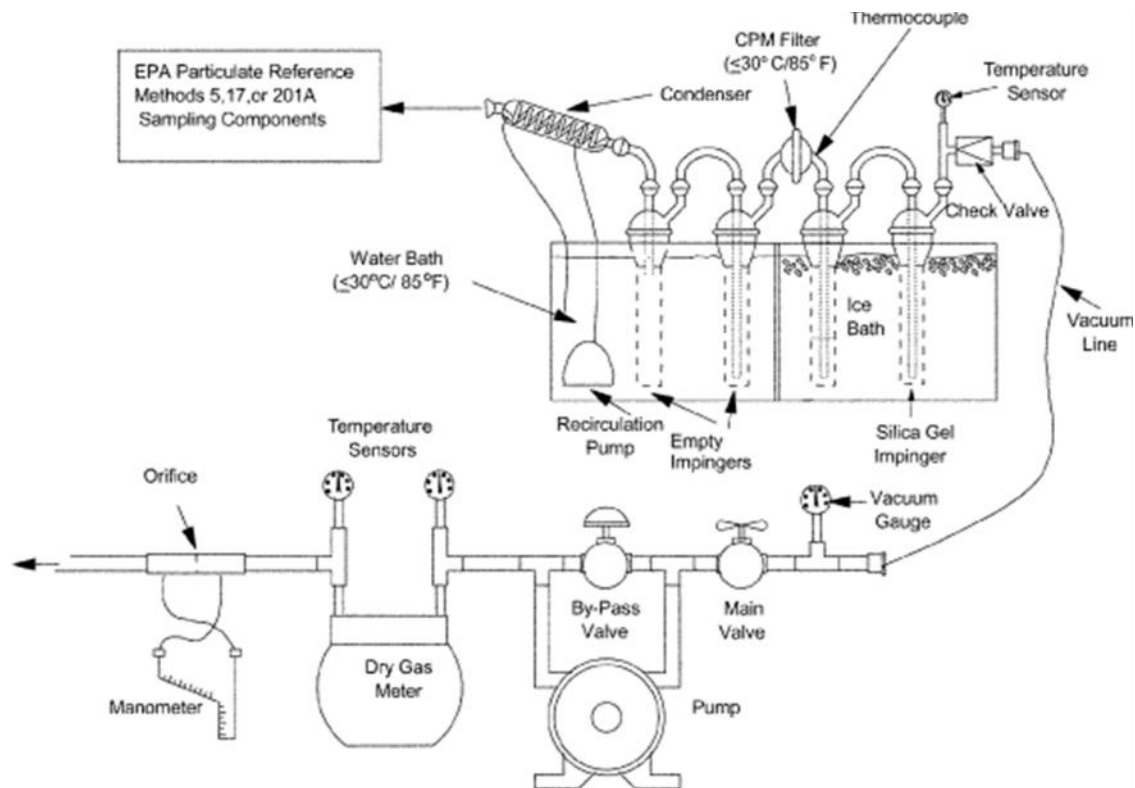
### Method for Determining Condensable Particulate Emissions from Stationary Sources.

Page 1 / 5

#### SUMMARY

Particulate matter (PM) is withdrawn isokinetically from the source in accordance with EPA Methods 5, 17 or 201A. The Method 5, 17 and 201A front half sampling train components remove filterable particulate matter before the sample gas is drawn through the Method 202 components to collect condensable particulate matter (CPM). The Method 202 sampling train components begin with a glass coil condenser, followed by two dry impingers, and a Teflon filter. Condensate collected in the dry impingers and on the Teflon filter is recovered. The condensate and filter are extracted and organic and aqueous fractions are dessicated and weighed to determine the mass of total CPM.

#### SAMPLING TRAIN



#### Components:

- 1. dropout impinger, empty
      - 2. modified Greenburg-Smith impinger, empty
  - 1. Modified Greenburg-Smith, 100 ml H<sub>2</sub>O
    - 2. Modified Greenburg-Smith, indicating silica gel
- Umbilical with leak-free vacuum line
- Vacuum gauge, leak-free pump, temperature sensors and a calibrated dry gas meter
- Dual inclined manometer or equivalent for measuring velocity head and orifice values

Revised: 06/4/2020



## EPA Method 202

### Method for Determining Condensable Particulate Emissions from Stationary Sources.

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#### SAMPLING PROCEDURES

- ) Select sampling site and minimum number of sampling points according to EPA Method 1. Refer to Method 4, 17 or 201A for sampling specifications
- ) Assemble the Method 202 sampling train components as shown above, weigh the impingers, place water around the first two impingers, activate the condenser recirculation pump, and place crushed ice around the third and fourth impingers.
- ) Conduct a leak check from the tip of the nozzle at a vacuum equal to or greater than the highest anticipated during testing. Ensure that the leak rate is 0.020 cfm before starting a test run.
- ) Place the probe at the first sampling point.
- ) Begin sampling at the isokinetic rate in accordance with EPA Methods 5, 17 or 201A.
- ) Traverse the stack using the predetermined sampling points.
- ) Conduct a post-test leak check at a vacuum higher than the highest vacuum observed during sampling.

#### RECOVERY PROCEDURES

- ) Weigh the impingers to determine moisture gain.
- ) Conduct a pressurized purge of the CPM train by transferring water collected in the condenser and dropout impinger into the backup impinger. If the tip of the backup impinger does not extend below the water level, add a measured amount of degassed, deionized ultra-filtered water. Purge at a minimum of 14 liters per minute using filtered ultra-high purity nitrogen.
- ) Container 1 (Aqueous liquid impinger contents) – Quantitatively transfer liquid from the dropout and the impinger prior to the CPM filter into a clean sample bottle (glass or plastic). Rinse the probe extension, condenser, each impinger and the connecting glassware, and the front half of the CPM filter twice with water. Recover the rinse water and add it to the same sample bottle. Mark the liquid level on the bottle.
- ) Container 2 (Organic rinses) – Rinse the probe extension, condenser, each impinger and the connecting glassware, and the front half of the CPM filter twice with acetone. Then repeat the entire rinse procedure with two rinses of hexane, and save the hexane rinses in the same container as the acetone rinse. Mark the liquid level on the bottle.
- ) Container 3 (CPM filter) – Place the filter in a labeled petri dish.
- ) Acetone Field Reagent Blank – Take 200 ml of acetone directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
- ) Water Field Reagent Blank – Take 200 ml of water directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
- ) Hexane Field Reagent Blank – Take 200 ml of water directly from the wash bottle and place it in a clean, leak-proof container. Mark the liquid level on the bottle.
- ) Field Train Recover Blank – After the first or second run, add 100 ml of water to the first impinger, purge and recover the assembled train as above. This blank weight will be subtracted from the field sample weights (max of 2.0 mg).

Revised: 06/4/2020



## EPA Method 202

### Method for Determining Condensable Particulate Emissions from Stationary Sources.

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#### ANALYTICAL PROCEDURES

- ) Container 3 – Conduct triplicate extractions of the inorganic fraction of the CPM filter using deionized, ultra-filtered water and combine with container 1. Conduct triplicate extractions of the organic fraction of the CPM filter using hexane and combine with container 2.
- ) Container 1 – Use hexane to extract the organic fraction and add it to container 2. Transfer the remaining aqueous fraction to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
- ) Container 2 – Transfer the organic fraction to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
- ) Acetone Field Reagent Blank - Transfer 150 ml of the acetone to a tarred beaker, evaporate to dryness at room temperature and pressure in a laboratory hood, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
- ) Water Field Reagent Blank - Transfer 150 ml of the water to a tarred beaker, evaporate to dryness, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
- ) Hexane Field Reagent Blank - Transfer 150 ml of the hexane to a tarred beaker, evaporate to dryness at room temperature and pressure in a laboratory hood, desiccate for 24 hours, and weigh to a constant weight to the nearest 0.1 mg.
- ) Field Train Recover Blank – Analyze following the same procedures as above.

#### QUALITY ASSURANCE

##### Equipment

- ) Pitot tubes, thermocouples, nozzles, and dry gas meters are calibrated annually.
- ) All glassware is cleaned and baked (6 hours at 300 °C) prior to field use.
- ) Probe, filter, and impinger exit temperatures are carefully monitored during testing to ensure the values are maintained within the appropriate range.
- ) The entire sampling train is leak checked post run from the tip of the nozzle at a vacuum equal to or greater than the maximum value reached during the test run.
- ) Sampling rate is verified to be within 10% isokinetic variation (90%-110%).
- ) The dry gas meter calibration factor is verified after field use to be within 5% of the annual value.

##### Samples

- ) New containers are used to collect samples.
- ) Each sample container is clearly labeled.
- ) A chain of custody is generated for all samples.
- ) Samples are transported upright in protective packaging.

##### Data

- ) Field data are recorded on prepared forms.
- ) Only reviewed spreadsheets are used to conduct data reduction calculations.
- ) All data and deliverables undergo peer review with a signoff form.

Revised: 06/4/2020



## EPA Method 202

### Method for Determining Condensable Particulate Emissions from Stationary Sources.

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#### CALCULATIONS

##### Dry Gas Volume:

$$V_{m(s)} = V_m Y \frac{T_s \left( P_{bar} + \frac{\Delta}{13.6} \right)}{T_m P_s}$$

- $V_{m(std)}$  Volume of gas sample measured by the dry gas meter, corrected to standard conditions, dscf
- $V_m$  Volume of gas sample as measured by dry gas meter, dcf
- $Y$  Dry gas meter calibration factor
- $T_{std}$  Standard absolute temperature, 528 °R
- $P_{bar}$  Barometric pressure at the sampling site, inHg
- $H$  Average pressure differential across the orifice meter, inH<sub>2</sub>O
- $T_m$  Absolute average DGM temperature, °R
- $P_{std}$  Standard absolute pressure, 29.92 inHg

##### Volume of Water Vapor Condensed:

$$V_{w(s)} = K_2 V_{lc}$$

- $V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf
- $K_2$  0.04706 ft/ml for English units
- $V_{lc}$  Total volume of liquid collected in impingers and silica gel

##### Moisture Content:

$$B_w = \frac{V_{w(s)}}{V_{m(s)} + V_{w(s)}}$$

- $B_{ws}$  Water vapor in the gas stream, proportion by volume
- $V_{w(std)}$  Volume of water vapor in the gas sample, corrected to standard conditions, scf

##### Condensable Particulate Matter (CPM) Concentration:

$$C_{cr} = \frac{m_{cr}}{V_{m(s)}}$$

- $C_{cpm}$  Concentration of condensable particulate matter in stack gas, dry basis, corrected to standard conditions, mg/dscf
- $M_{cpm}$  Total amount of condensable particulate matter collected, mg

Revised: 06/4/2020



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**CALCULATIONS** (CONTINUED)Isokinetic Variation:

$$I = \frac{100T_s \left[ K_4 V_{li} + \frac{(V_m Y)}{T_m} \left( P_{bar} + \frac{\Delta H}{13.6} \right) \right]}{60 \theta v_s P_s A_n}$$

$T_s$	Absolute average stack gas temperature, °R
$K_4$	0.002669 ((inHg)(ft))/((ml)(°R)) for English units
$V_{li}$	Total volume of liquid collected in impingers & silica gel, ml
	Total sampling time, min
$V_s$	Stack gas velocity, ft/sec
$P_s$	Absolute stack gas pressure, inHg
$A_n$	Cross-sectional area of nozzle, ft <sup>2</sup>